powers magnifying from 700–900 diams. Though successful in some instances, this method is for the most part wholly insufficient. (3) Staining sections. This was successful in many plants in demonstrating the protoplasmic connection. (4) Injection into organs. When injected slowly, under pressure, with a fluid capable of colouring protoplasm, if the injection took place in a sufficiently uniform way, the canals were rendered visible. By the methods thus indicated continuity of protoplasm was established in the stem and leaves of the box-tree, and in *Ficus elastica*.

NEW EDIBLE FUNGUS.—Mr. Colenso calls attention to the rapidly-increasing value as an article of export from New Zealand of *Hirneola polytricha*. This mushroom, first described from the East Indies and Java by Montagne, is of various sizes and shapes, some specimens measuring even a few inches. It is found in New Zealand growing on the trunks of trees, both on living and on decaying ones, especially on the latter while standing, particularly on the stems of *Corynocarpus lævigata* and on *Melicytus ramiflorus*. Both of these are endemic. The former is mostly confined to the sea-shore, where it often forms dense and continuous thickets. The latter tree is scattered plentifully throughout the country. When dry, the mushroom becomes shrivelled up, and is as hard as horn; when wet, it is soft and elastic, almost subgelatinous. It grows in compact gregarious masses. The market for this fungus is China, where it is largely used by the Chinese in soups. It appears that another species of the same genus indigenous in North China has long been an article of commerce. Mr. Berkeley notes of our British species, *H. auricula-judæ*, that it was once a popular remedy for sore throats, and adds that it is still occasionally sold at Covent Garden Market. The New Zealand species is plentiful, and obtained at little cost, the drying of it being an easy matter. Originally the price paid to collectors was a penny per pound; now it is nominally twopence halfpenny, while its retail price in China is five times this. The *declared* value per ton at the Customs ranges from 33*l*. to 53*l*. a ton, and is doubtless much below its real value. During the last twelve years some 1858 tons of this fungus were exported, chiefly from the ports of Auckland and Wellington, and of a declared value of almost 80,000*l*.—(*Trans.* Penzance Nat. Hist. and Antiq. Soc., 1884–85.)

WORMS IN ICE.—Prof. Leidy had examined a block of ice which was part of the stock of ice stored at Moorestown, N.J., and had been nearly a year in store; it was full of air-bubbles and water drops. On being melted a number of worms were liberated, and proved to be in a living and quite active condition. It is probable that while imprisoned in the ice they may not have been frozen, but perhaps remained alive in a torpid state in the water-drops; but it seems remarkable that these animals should remain so long alive in the ice, and yet die, as they did, almost immediately, in the melted ice-water. Of course the fact points to the advisability of not employing spongy ice as an article of food. Dr. Leidy, believing the form to be as yet undescribed, gives a diagnosis of it under the name *Lumbricus glacialis*; it is from 4 to 6 centimetres long, of from 35 to 50 segments; oral segment unarmed, eyeless; succeeding segments with four rows of podal spines, in fascicles of three.—(*Proc. Nat. Sci. Philadelphia*, December 22, 1885.)

STAR-FISHES FROM SOUTH GEORGIA.—Dr. Studer describes a small collection of star-fishes made by Dr. v. d. Steinen, the naturalist of the German Polar Expedition in 1882-83, who had a meteorological station at South Georgia. Of the 14 species collected, 9 belonged to the family Stelleridæ, and 7 of these were new, 5 to the Ophiuridæ, of which 4 were new. Most were collected in quite shallow water. The general character of the fauna is like that of Kerguelen Land; and, to assist the comparison, Dr. Studer gives a comparative list of the known species from the South American (Falkland Islands, Magellan Straits) district and that of Kerguelen Land. All the new species are well figured in two plates which accompany the memoir.—(*Aus dem Jahrbuch der wissens-Anstalten zu Hamburg*, xi. 1885.)

GEOGRAPHICAL NOTES

THE last number (15) of the *Journal* of the Straits Branch of the Royal Asiatic Society contains several papers of much geographical interest. In the first, Mr. Swettenham describes a journey across the Malay peninsula from Kwala Bernam in Perak, through Pahang to Kwala Pahang on the east coast. The paper is in the form of a journal, but, unfortunately, the accompanying sketch-map is so defective as to be quite useless to assist the reader in following the narrative. Père Couvreur, of the Missions Etrangères at Singapore, contributes an account of a recent journey through Laos from Bangkok to Ubon, a town on the Szimûn, a tributary of the Mekong, including a visit to the ancient Khmer city of Puthai-Saman, the monuments and architecture of which make it similar to the renowned Angkor, but on a reduced scale. To the people of the country these magnificent ruins are the work of avals, so completely has all trace of the great civilisation of which they are the eloquent witnesses disappeared from Cambodia. This paper is also in the form of a journal, but is not accompanied by a map. There are several other papers of interest (such as the translation of old Valentyn's account of Malacca, and the account of the Dutch expedition of 1877–79 to the interior of Malacca), but these are not original to the Straits Asiatic Society.

THE *Verhandlungen* of the Berlin Geographical Society just published (Band xiii., No. 1) contains an account, by Dr. Wolff, of the journey of the expedition sent out by the African Society in 1884 from San Salvador to the Quango and back, and Dr. Diener writes on the mountain system of Lebanon, on which he has also a paper, already noticed, in the February *Petermann*. The current *Zeitschrift* (Band xx., Heft 6) of the same Society is largely occupied by a bibliography of the works, papers, maps, &c., relating to geography published during the year ending November 1885. There is, however, a curious list of the lengths and drainage areas of 376 rivers of the world. These figures are necessarily approximate only in most cases. It is noticeable that, while the Mississippi is 5882 kilometres in length, and the Amazon only 4929, the drainage area of the former is less than half that of the latter, the figures being: Mississippi, 3,201,545, and the Amazon 7,337,132, square kilometres. The only other paper in the number is an exceedingly interesting one by Herr Rohde, on the Terenos tribe, which inhabits the district to the west of the Brazilian town of Miranda, and stretches as far as the Bolivian frontier. They are really Chaco Indians who have migrated from Bolivia. The writer describes, all too briefly, their appearance, mode of life, occupation, and customs—especially their festivals.

THE Austrian traveller, Mr. C. Hermann, who started on a West African exploring tour in April last, has returned to Vienna. Having visited Liberia, Cameroon, Eloby, Gaboon, and other points on the coast, he arrived at the Congo early in July, and expected the arrival of Dr. Lenz at Banana. In order to engage the necessary porters for Dr. Lenz's expedition he went to Loango, but returned to Banana without having succeeded. He left Dr. Lenz on October 20 and returned to Europe.

DR. BERNHARD SCHWARZ writes from Monrovia (Liberia), under date January 23, as follows:—"As chief of an official expedition 'for the investigation of the up-country districts of Cameroon,' I reached Cameroon on November 6 last, and thence I proceeded eastwards with forty Bakwiri porters (from the Cameroon Mountain) on the large main road leading to the interior over the magnificent slopes of the Cameroon Peak. I penetrated through the immense virgin forests, which are peopled with elephants, and in which coffee, india-rubber, &c., grow, and and safely reached the interior of our colony, never before visited by a white man on account of the energetic resistance offered to all traders by the natives. Here live the Bafarami in the Bafon Land, hitherto not even known to the world by name. They cultivate the soil and keep cattle, and are comparatively civilised. I visited Kumba and Kimendi, their large towns, but on account of an attack made upon us by 500 armed slaves I could not see the upper Calabar, whieh must have been quite near. The maps hitherto existing of this interesting district, which may be of the highest importance for the whole future of our colony, are either insufficient or else quite wrong."

THE SUN AND STARS[1]

WHEN we have to consider the stars taken in their entirety, it is obviously convenient that we should begin with the sun, because in that way we shall be enabled to go outwards from the known; since it is easily to be understood that it is within

[1] A Course of Lectures to Working Men delivered by J. Norman Lockyer, F.R.S., at the Museum of Practical Geology. Revised from shorthand notes.

our power to know very much more about the sun, which is the star that lies nearest to us, than about the other stars, so far as detailed structure, at all events, is concerned, for the reason that the sun, although actually so far away, is relatively very near to us.

The Sun's Distance[1]

The distance of the sun we may take to be about 93,000,000 of miles, and, although that seems a long way in terrestrial reckonings, twice that distance is the smallest base line which astronomers can use in dealing with the distance of the star which is next nearest to us, to say nothing of the millions of others more remote. The sun, from being relatively so near to us, appears as a body of a different order. The stars proper, however powerful the telescope with which we regard them, appear to us as the finest points imaginable, whereas the sun gives us the appearance of a circular disk, this disk being the projection of a sphere. That part of the sun with which we are most familiar is in fact a sphere of something like 860,000 miles in diameter; hence, taking the diameter of this world of ours roughly at 8000 miles, the diameter of the sun is more than 100 times as great.

The moon, the nearest celestial body to us, journeys round us at the relatively small distance of about 240,000 miles. The

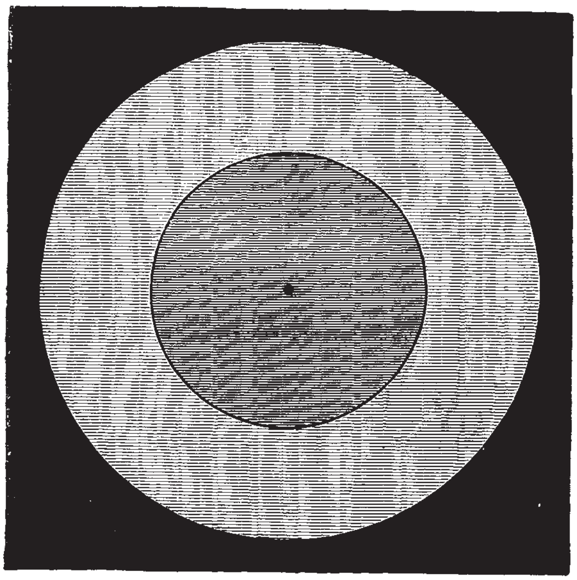

Fig. 1.—The orbit of the Moon and the circumference of the Sun compared.

accompanying drawing will enable us to compare the orbit or path of the moon round the earth and the space which it incloses, with the actual circumference of the sun (Fig. 1).

In the centre we have the earth very much larger than it ought to be, and the inner disk represents the space included in the orbit of the moon. The outer one represents the disk of the sun; so that it is clearly seen that if the sun were a soap bubble it would be quite easy for the earth's attendant satellite, the moon, to carry on its revolution inside it; in fact the orbit of the moon would not lie very much past half-way from the centre of the earth to the circumference of the sun.

The Sun's Envelopes

The next point which has been made clear by the work of the last quarter of a century, let us say, is that this central nucleus which we see ordinarily and call the sun, is only, after all, a very small part of it. Outside it there is a shell very exquisite in colour. This might be described as a sort of sea surrounding the central nucleus, if that expression did not give the idea that the nucleus itself was a solid, which it is not.

This first envelope, the *chromosphere*, as it is called, represents a sort of atmosphere or sea surrounding what is named the *photosphere*, to a height varying, say, from 5000 to 10,000 miles. I have said that it is exquisite in colour. It is of an intensely brilliant pearly white at the base, and of a magnificent scarlet, as a rule, higher up. But this is not the outside of the sun by any means. Further from the centre, again, there is another region, which we may call the inner corona, overlying the photosphere and chromosphere; the height of this atmosphere—I mean the distance from the top of it on the average down to the photosphere—we may again roughly take at something like 100,000 miles. Not very many years ago, in the text-books we were told that the earth's atmosphere only extended to a height of 50 miles, so that it can be easily recognised that we are dealing with an atmosphere on a very large scale indeed when we come to touch the sun.

These portions of the sun's atmosphere are only very rarely seen under the best conditions. We can feel, so to speak, the lower reaches every day in our observatories, but we can only see them when the sun is eclipsed. When, in an eclipse, we can get a good sight of the inner corona, what we see is very beautiful indeed, because we not merely get a pearly shell of light, which, roughly speaking, may be taken to be 100,000 miles high, but we see stretching into it from and through the chromosphere beautiful and curious objects called "red flames," or "prominences," or "protuberances."

Have we yet finished with the solar envelopes? No; there is still another. There is still an upper atmosphere, and to this I must ask you to give a height of anything you like between half a million of miles and a million and a half; and I speak thus indefinitely for the reason that the exact limit is at the present moment occupying those who are concerned in these matters. The limit of course you will understand is a limit which can only be determined during eclipses. Now the sun is only eclipsed for something less than a week in a whole century over the whole earth, and I suppose that if an observer of eclipses were to give his whole time to them he could not spend more on the average than six minutes every two years, so that the time is not excessive in which the astronomer either has to make observations or to make up his mind as to what he sees. You must not, therefore, be surprised when I give you this large choice. If we call it roughly a million of miles, we at all events shall not be very far off the truth, even supposing the height to be constant; but it would appear indeed that the height varies every time we have a chance of observing it. On that point we shall have a great deal to say further on.

When we come to this outer atmosphere, we pass from one with a more or less concentric boundary, to one with a most irregular outline, full of strange forms varying in an almost inexplicable manner from eclipse to eclipse.

In the eclipse of 1878 one of the observers who took special precautions to shield his eye from any brighter light at the moment that the eclipse took place, imagined, or saw, the fainter portions of the solar corona, or some solar surrounding, extending to several diameters. The outer corona is not only very strange in its appearance, but wonderful in colour, and full of detail for a considerable distance from the dark moon.

To sum up some of the principal points—by no means all of them—we may say, first, that its outline is very irregular; that there seems to be a flattening, or very often two opposed flattenings, at opposite ends of a solar diameter. This tends to make the thing look very often more or less square. In all parts of it, irregularly (by which I mean that you cannot predict quite where they will be), you get radial rifts in which the light is much less intense than elsewhere.

I have, then, indicated that the sun that we see is not the whole of the sun. Hence, when we study the stars we shall probably find that we have not only to take into account the phenomena presented by the sun as we ordinarily see it, but others associated with those parts of the sun which are only revealed to us from time to time, and the possibility that such phenomena as we see on the sun may be enormously intensified in other bodies.

The Sun's Rotation

The next question that we have to put concerning the sun is this:—Since it is a sphere as the earth is, and since the earth rotates on its axis, does the sun rotate on its axis? How are we to answer that question?

[1] The most recently determined value of the sun's distance depends upon Prof. Newcomb's determination of the velocity of light. This velocity Prof. Newcomb values at 299,860 kilometres per second, with a probable error of 30 kilometres either way. Combining this with Nyrén's value of the constant of aberration 20″·492, the solar parallax = 8″·794, which gives a distance of 149·61 millions of kilometres. This equals 92,965,020 British statute miles.

in this way. Sometimes when we look at the sun it is a beautifully pure hemisphere, almost equally illuminated all over it with the exception of a darkening towards the edge, about which more presently; but at other times these conditions are altered. It is more or less covered with what are called spots. It is more than two centuries and a half ago since it was clearly demonstrated that these spots belong to the sun itself; and it will be clear, therefore, that if these spots really do belong to the sun, or, to be more precise, are phenomena occurring in the photosphere—which is the part of the sun which we usually see, the rotation of the sun will be demonstrated if these spots are found to travel regularly across its disk; whereas its fixity will be demonstrated if we find that the spots do not move at all. A very great deal of work has been done in this direction, and it has been determined beyond all question that the sun does rotate like the earth and like the other planets of our system, and that it rotates from west to east, contrary to the hands of a watch, as the earth does.

We next have to consider the plane of this rotation. The earth moves round the sun in a plane which we call the plane of the ecliptic; but we know that the earth does not rotate in this plane. There is a difference of $23\frac{1}{2}^\circ$ between the equatorial and ecliptic planes. We therefore say that the earth's axis is inclined $23\frac{1}{2}^\circ$ to the plane of the ecliptic. Further, if we wish to know the particular direction in which it is inclined, we must determine the longitude of the ascending node, and this done, we can determine the star towards which the earth's axis points.

Well, can we get out these facts with regard to the sun? Yes. The sun does not rotate in the plane of the ecliptic as we might first of all imagine that it would do. Its axis is inclined at about 7° to that plane, and its ascending node does not lie in the same direction in space as the ascending node of the earth, but it is distant from it some 73°. We have two very accurate determinations of these two sets of data. Carrington's first value gives—

	°	′
Longitude of node	73	40
Inclination	7	15

We see, although the sun's rotation does not take place in the plane of the ecliptic, it does not take place in a plane very far removed from it.

Spörer, a German observer, who has taken up this question since Carrington, makes some very slight changes. He gives—

	°	′
Longitude of node	74	36
Inclination...	6	57

The right ascension of the star towards which the sun's pole points is 18 hours 14 minutes, and its declination 64° N. It lies half-way between our own pole star, and the bright star α Lyræ.

We may now carry these considerations a little further. When the earth passes through the nodes of the sun's equator, that is to say, when the axis of the sun is at right angles to the line joining the centre of the sun and the centre of the earth, it will be perfectly clear that the spots will appear to travel straight across the disk. The two times of the year in which this occurs are June 3 and December 5. The two poles of the sun at those times are in fact on the sun's limb, and it is that condition really which makes the path straight (Fig. 2).

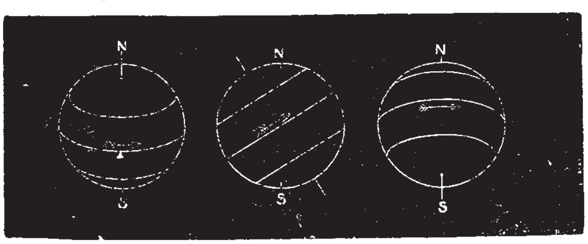

FIG. 2.—Position of the Sun's axis, and apparent paths of the spots across the disk, as seen from the Earth at different times of the year. The arrows show the direction in which the Sun rotates. The inclination of the axis is exaggerated, so that the effect produced may be more clearly seen.

From June 3 to December 5 the north pole of the sun is gradually moving earthward. It will be clear, therefore, that during that time the spots, instead of travelling in straight lines across the disk, will gradually have their paths curved with the convexity downwards. When we have got to December, from that time to the next June it is the south pole that will be inclined towards the earth; and therefore the spots will then move with the convexity of their paths upwards.

So far I have said nothing about the period of the rotation of the sun. The question of the sun's rotation is not quite such a simple matter as it might appear at first sight. Here we must be quite honest to the first workers, and I must tell you that the actual facts appear to have been clear to a man who lived three centuries ago—Scheiner—who was the first to observe the spots with any very great and continuous care; he made what appeared to him the extraordinary discovery that the spots which were nearest to the sun's equator appeared to travel at a quicker rate than those which were nearer the sun's poles. The average time in which the spots appear to cross the sun is about 28 days. That you will understand is what we may term the synodic period, because the observations are made from the earth, which is moving in the same direction as the spots while the observations are being made. Making the correction for the movement of the earth, and getting the actual period, the 28 days have to be brought down to something like 26 for an average spot. Carrington, whose results for the plane of rotation I have already stated, also paid very great attention to this point, and to his work, and also to Spörer's, we owe very much of our present knowledge on this subject.

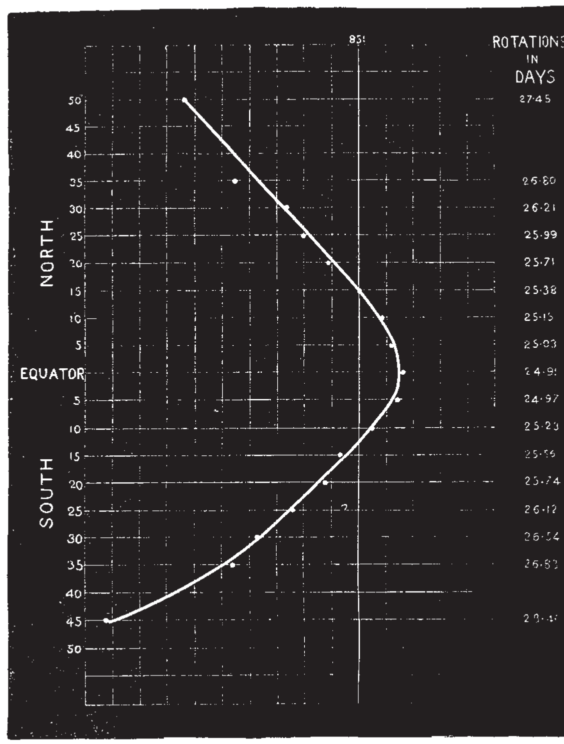

FIG. 3.—Curve showing the period of rotation of the photosphere in different latitudes north and south from Carrington's observations; 851′ of solar longitude per diem = rate of rotation in lat. 15° N. The vertical lines represent differences of 10′ of longitude, + to the right, − to the left, of the line cutting the curve in lat. 15° N.

Carrington, from the observation of some thousand spots, came to the conclusion that the photosphere in which these spots are supposed to float really moves more rapidly at the equator than it does away from it, in the manner that Scheiner had suggested, in such a way that the movement at the equator really takes place in, as near as may be, 25 days, perhaps a little less; but that in latitude 30° there is a slackening off of a day and a half, so that it takes a spot in latitude 30° north or south not 25 days, but $26\frac{1}{2}$ days to make its movement right round; if we go as high as latitude 45°, we have to add on

still another day, and then we find that the rotation takes $27\frac{1}{2}$ days.

Several distinguished men have endeavoured to formulate a law, a mathematical statement, by which, given the movement in one latitude, we may determine it for all other latitudes, and several of them have very nearly succeeded in doing it; but they all confess that it does not amount to much at the end of the chapter; by which I mean that the formula after all contains no physical basis. It is what is termed an empirical formula.

The formulæ to which I have referred may be given in this place. In them all x = daily motion in minutes of solar longitude, and l = latitude. They are as follows:—

Carrington	$x = 865' - 165' \sin \frac{7}{4} l$
Faye	$x = 862' - 186' \sin ^2 l$
Spörer	$x = 1011' - 203' \sin (41° 13' + l)$
Zöllner	$x = \dfrac{863' - 619' \sin ^2 l}{\cos l}$

Certainly we have here, as I think I shall be able to show you by and by, one of the points in the mechanism of the sun which it behoves those interested in solar physics to work at with the utmost diligence.

We have now got the fact that the sun, like the earth, rotates on its axis; that the inclination of its axis to the plane of the ecliptic is much less than the inclination of our axis; that its node lies in a different longitude; and that the photosphere, instead of being a solid thing like the surface of our earth, is a something which makes its journey round the sun's centre in $2\frac{1}{2}$ days less time in the central portions than it does half-way between the equator and the poles.

The Sun's Density

Now then let us come to another point. We are accustomed, in dealing with the earth and comparing it with other planets, to refer to the density of the various bodies. We say, for instance, that the density of the earth is $5\frac{1}{2}$ times greater than the density of water; that is to say, that the earth put in one scale would weigh down $5\frac{1}{2}$ earths of the same size, if they were made of water, put in the other. And we say, further, that the density of the earth is about the same as the density of Venus and of Mars; but the density of the other planets is very much less. We know on the earth that water is less dense, for instance, than mercury. We know that spirit is less dense than water. We can, indeed, put water in a tumbler, and by proper means add the spirit so that it will float on the top of the water. We do not generally do that. Again, we put lead into water, and it sinks. We put a cork into water, and it floats. All these represent different orders of density. The same thing happens with regard to gases. We know that hydrogen is less dense than oxygen and nitrogen, and so on.

Now, what is the density of the sun? Is the sun denser than the earth? No; according to the books it is just about a quarter as dense as the earth, so that it is a little denser than water. In fact, if we take water as our unit of density, if water equals 1, the density of the sun is 1·444. If we take the density of the earth as 1, then the value is about 0·25—practically, a quarter.

Now, these are the values given in the books, but I think that possibly we must call them in question. They have been determined by taking the volume of the sun as given by the diameter of the photosphere—860,000 miles. Now, we have had to concede 100,000 miles for the height of one atmosphere above the photosphere, and 1,000,000 miles for another, and it is not fair that those atmospheres should be left out of consideration. If we include these atmospheres, though we do not alter the mass, we alter the volume. If we put the same mass into a bigger volume, we naturally reduce the density. Now, if we take the atmosphere of the sun as extending to 100,000 miles above the photosphere, that will give us a radius of 530,000 miles, instead of 430,000 miles, and we shall, as nearly as may be, double the sun's volume. Therefore we shall have halved the density. Instead of being a quarter as dense as the earth, it will only be one-eighth as dense; and, instead of being just denser than water, it will be a little over half the density of water. For my own part, I think that this 100,000 miles is not sufficient. I think that it is the minimum. I think that most students of solar physics would agree that a height for this purpose of 500,000 miles above the photosphere would be probably nearer the mark. That will give us exactly ten times the volume of the sun bounded by the photosphere, so that the densities will be reduced to the tenth; we shall get a density then of about one-eighth of water. This, of course, is the average density; it is the density of the whole volume in which the mass is supposed to be diffused—the mass which is a fact which we cannot get out of, and which has a definite relation to the mass of our own earth. Now if these arguments are of any value we must concede that the density of the sun is very low indeed, much lower than that of any planet or satellite with which we are acquainted; so that we are perfectly justified in saying that it is an enormous globe of gas, by which I do not mean that it is absolutely and completely gaseous to the core. The gases of the centre—gases under very great pressure—may put on the appearance, if they do not put on all the physical properties, of liquids; but be this as it may, in any region that we can get at, unfortunately limited to something like 400,000 miles away from the centre, we are undoubtedly dealing with masses of gas.

The Sun's Heat

Another point in which we find an enormous difference between the sun and any other body that we investigate in the solar system is this—that the sun is an *intensely heated* globe of gas. It is of no use to use any adverbs to tell you how hot it is, and, unfortunately, there are very few available facts; so that I must ask you to give your imagination play, and to believe that it is very, very hot. The values that have been suggested by various men of science vary between 18,000,000° and 3000°. You may take your choice. The fact is, I think, that we are not yet in a position to find out the very best method of determining the solar temperature and then marking it down in an absolutely perfect manner, for the reason that the more one knows about the problem, the more one sees how terribly complicated it is.

No doubt we have here a field of work of the very highest interest. Of course, when men of science have stated that the temperature of the sun is 18,000,000° or 3000°, they have referred to the temperature of that part of the sun which is available to our observation, and to the hottest parts of it. Naturally, if the sun be a heated globe of gas, on the outside it must be cool, so that they do not mean that this globe of gas is equally heated throughout, but that the hottest part of it—the part which sends us the effective heat which we try to measure—is at that temperature.

There is one other very interesting question connected with the remark that the atmosphere must cool to the outside. This time last century the idea was that the sun was a habitable globe just like the earth. An intense heat and light were granted to an exterior envelope, but it was imagined that there was a reflecting stratum inside which sent all the heat away earthward, and planet-ward, with redoubled energy, while at the same time it shielded the inhabitants who were below this reflector from the direct light and heat of this envelope. That was Sir William Herschel's idea. We know now that these things cannot be so. If the walls, and ceiling, and floor of this lecture theatre were incandescent, you may depend upon it that, in spite of any number of reflectors we should soon be incandescent too. According to what is now known as Prevost's theory of exchanges, anything inside a heated chamber must, if you give it time, get to the temperature of the walls of that chamber, for the reason that the walls would be giving heat to the object inside, and the object would be sending the heat back again if it had a surplus of it, and you would get this exchange going on until the temperature of everything inside would be the same as the temperature of the envelope; so that we are now perfectly certain that, if the temperature of the photosphere of the sun, let us say, be 3000°, or 30,000°, or 3,000,000°, the temperature of the internal part of the sun will not be less. It may be much more. So that we have to give up all that beautiful idea of the habitability of the sun by creatures like ourselves.

Now, if this mass of gas, a million and a half of miles in diameter, let us say, is coolest outside, and hottest at the centre—which I think you will grant—there must be a gradual increase both of temperature and of pressure towards the centre. The observations which have been made during eclipses indicate with sufficient definiteness that there is an undoubted increase of temperature towards the centre, and that the various appearances which we get at the photospheric level really mean that at this point, where the pressure is greater than at any superior level—as the pressure in London is greater than the pressure on the top of Mont Blanc—the temperature also is higher, as is indicated by the extreme brightness of the objects

seen, as compared with the dimming off of those parts of the solar atmosphere which are farther removed.

Now, can we watch this? Can we study it so that we can find out all about it? Well, not entirely. The photosphere which carries the spots to which I have referred allows us certainly to see the phenomena of the spots, but then it acts as a veil that prevents us seeing anything nearer the centre of the sun, whatever it is. It practically serves as a veil for all the underlying phenomena. Also, as I have mentioned, the outer corona is only visible for a few minutes in each generation; so that, when we attempt to watch the totality of the phenomena from the top of that magnificent radius down to that part of it which cuts the photosphere, there are difficulties of every kind supervening; we can only continuously and effectively study those regions of the atmosphere just above the photosphere, or in other words the phenomena included in the inner corona.

Absorption of the Sun's Atmosphere

But in addition to this there is something else that we can do, though this work is not so valuable, as its results are too general. We can study the general absorptive effect of the whole atmosphere above the photosphere by dealing with ordinary sunlight reflected from a cloud.

The three kinds of absorption which we recognise in spectrum analysis are these. First of all, we have a selective absorption which enables us to determine the presence of the incandescent vapour of any particular metal in the atmosphere of the sun.

Next it was pointed out in the year 1873[1] that the absorption of some elementary and compound gases is limited to the most refrangible part of the spectrum when the gases are rare, and creeps gradually into the visible violet part, and finally to the red end of the spectrum as the pressure is gradually increased. It looks very much as if all the permanent gases, or all gases and vapours at a temperature below that which enables them to give out bright lines or flutings, really possess this kind of absorption, and we know that the absorption of that kind at the sun is enormous, because the blue spectrum of the electric light is very much longer—six or seven or eight times—than the spectrum of the sun, because we get an ultra-violet radiation from the electric light which has been stopped in the atmosphere of the sun. As there are permanent gases in the sun's atmosphere the same conclusion is good for it also. If this absorption both here and at the sun were taken away, it is clear that the sunlight would be much bluer than it is at present. Prof. Langley, of the United States, who seems to be unaware of the results arrived at in 1873, has recently made the same announcement.

There is one other kind of absorption also. We have a general absorption—an absorption working equally upon all parts of the spectrum, which we may call general absorption in its true sense—such absorption, for instance, as we should get by mixing soot with water or smoking a glass and holding it in front of the sun—this would cause a considerable dimming of the light.

We can make this general examination of the atmosphere of the sun by simply observing the spectrum of sunlight reflected from a cloud; but it will be readily understood that, although in that case we shall be able to study the indications of selective absorption and the absorption of the blue end of the spectrum due to such gases as chlorine, and the general absorption of the spectrum due to the existence of solid particles; it will still be an inquiry which will only deal with the matter in its most general aspect, and we shall not be able to localise the exact regions in which these absorptions take place. Further we may say that the result of this study of the absorption of the solar atmosphere taken as a whole is chemical and statical merely. There is nothing dynamical about it. It tells us most important facts concerning the chemical constitution of the sun's atmosphere, taken as a whole, without localising the region in which any particular substance which we find to be absorbing is absorbing; but it does not tell us whether this atmosphere of the sun, which roughly we may accept as about a million of miles high, is in violent movement, or whether it is at rest.

There is, then, very much more to be done before we are fully in presence of the causes of the phenomena to which I have called attention, which stare us in the face every time we look at the sun, either when it is eclipsed, or when it is not.

J. N. LOCKYER

(*To be continued.*)

[1] *Phil. Trans.*, 1873, vol. clxiv. part 2, p. 491.

SCIENTIFIC SERIALS

THE numbers of the *Journal of Botany* for January and February contain no papers of very great importance. Messrs. H. and J. Groves record the addition of two new species to the British Characeæ: *Chara intermedia* and *Nitella capitata*, with figures of both.—Mr. J. G. Baker attempts to trace the relationship between the British and the Continental forms of the difficult genus *Rubus*.—Another addition to the British flora is recorded in *Equisetum littorale*, by Mr. W. H. Beeby.—Most of the other articles relate to descriptive or geographical botany.

THE most important paper in the *Nuovo Giornale Botanico Italiano* for January is an account by Sig. F. Morini of a new disease of cereal crops caused by the attacks of a hitherto undescribed parasitic fungus, *Sphærella exitialis*, allied to *S. graminicola* and *S. Tassiana*.—Sig. Pichi investigates the nature of the reddish-brown spots on the stem of *Bunias Erucago*, which he finds to come under the head of glandular emergences; and Sig. Cavara describes some singular anomalies and monstrosities in the flowers of *Lonicera*.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, January 14.—"The Coefficient of Viscosity of Air." By Herbert Tomlinson, B.A. Communicated by Prof. G. G. Stokes, P.R.S.

The author employed the torsional vibrations of cylinders and spheres, suspended vertically from a horizontal cylindrical bar, and oscillating in a sufficiently unconfined space. The bar was suspended by a rather fine wire of copper or silver attached to its centre, which, after having been previously subjected to a certain preliminary treatment with a view of reducing the internal molecular friction, was set in vibration.

The coefficient of viscosity of air was obtained from observations of the diminution of the amplitude of vibration, produced by the resistance of the air to the oscillating spheres or cylinders attached to the horizontal bar, arrangements having been made so that the vibration-period of the wire should remain the same, whether the cylinders or spheres were hanging from the bar or not. In deducing the value of the coefficient of viscosity from the logarithmic decrement, the author has availed himself of the mathematical investigations of Prof. G. G. Stokes.[1]

Five sets of experiments were made with hollow cylinders and wooden spheres, in the construction and measurement of which considerable care was taken. When the cylinders were used arrangements were made to eliminate the effect of the friction of the air on their ends. The following are the results:—

Cylinders

Length in centimetres	Diameter in centimetres	Vibration-period in seconds	Temperature of the air in degrees Centigrade	Coefficient of viscosity of the air in C.G.S. units
60·875	2·5636	6·8373	12·02	0·00018171
60·885	0·9636	7·0590	14·63	0·00018122
60·875	2·5636	3·0198	11·69	0·00018024
53·175	2·5636	2·9994	10·64	0·00017845

Spheres

6·364	2·8801	9·35	0·00017820

Maxwell has proved[2] that the coefficient of viscosity of air is independent of the pressure and directly proportional to the absolute temperature. We can, therefore, calculate from the above data what would be the value of the coefficient of viscosity at 0° C.; and when this is done, in the case of each of the five sets of experiments, we obtain the following values:—

Set of experiments	Coefficient of viscosity of air at 0° C.
1st	0·00017404
2nd	0·00017201
3rd	0·00017284
4th	0·00017359
5th	0·00017230

The mean of these numbers is 0·00017296 with a probable

[1] See Prof. Stokes's paper "On the Effect of the Internal Friction of Fluids on the Motion of Pendulums," *Trans.* Camb. Phil. Soc., vol. ix. Part II., 1850.

[2] *Phil. Trans.*, 1866, vol. clvi. Part I.